# Infrared Emission from Igneous Rocks during Stressing: Contribution to Understanding Pre-Earthquake "Thermal IR Anomalies"

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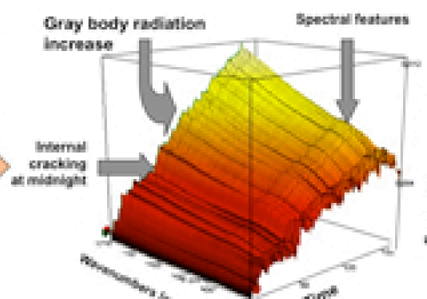
## INTRODUCTION

"Thermal anomalies" are TIR emission from the earths surface retrieved by satellites prior to seismic events. Satellite TIR data shows that before an imminent earthquake, the earths crusts passes through a preparatory phase. Accumulation of stress and the build up of pressure, leads to a black body radiation and additional emission bands. Field and laboratory experiments tested on igneous rocks show a broad IR emission bands. These observations suggest that the pre-earthquake "thermal IR anomalies" as seen in night-time satellite IR images around the epicentral regions of impending seismic activity contains both a thermal (blackbody) and a stimulated IR emission component. This indicates that heat is dissipated from the earth crust only when stress and pressure build up has occurred.

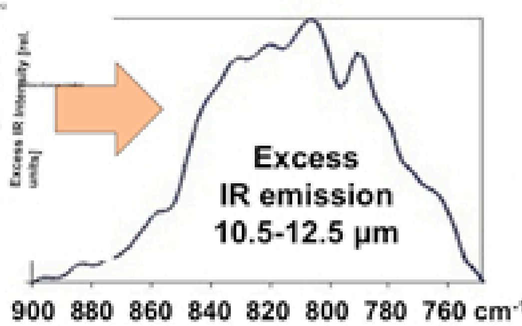
## METHODOLOGY

Sierra Nevada granite and Aromas gabbro-diorite. Stressed with Bustar up to failure. Continuous recording IR emission (8-10 hrs). Using Bruker Vertex 70 w/emission attachment and Bruker EM27.

Bruker EM27



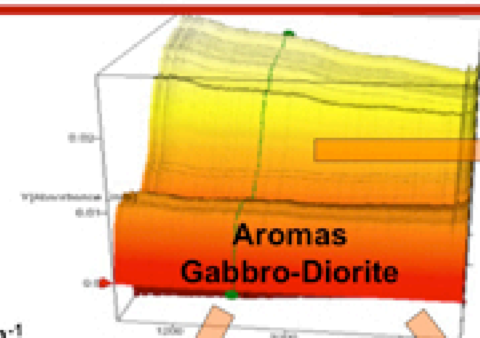

Sierra Nevada Granite

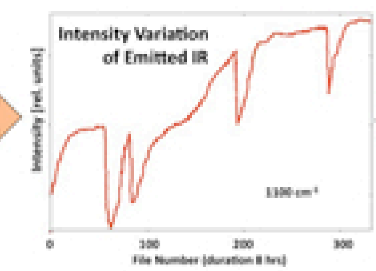




## ABSTRACT

- When Earth's crust is stressed, "Thermal IR Anomalies" appear around the future epicenter as seen in night-time satellite images.
- Defect electrons (positive holes $h^\bullet$) in the $O_2$ anion sublattice exists in form of dormant, electrically inactive defects as peroxy links ($O_3Si$-OO-$SiO_3$).
- Positive holes are activated by stress with an activation energy of ~2.4eV and can flow out of the stressed rock volume over meters of in the laboratory and are suspected to flow through kilometers of rocks in the Earth's crust.
- When positive holes reach the surface, they recombine.
- During recombination part of the activation energy is recovered.
- Pairs of vibrationally "hot" oxygen anions equivalent to 25,000 to 30,000K.
- Excess IR emission due to downward transitions between excited states.
- Excess IR emission bands fall into the range of 300K thermal IR maximum.
- In addition, the "hot" oxygen anions "kick" their neighbors, transferring energy non-radiatively, causing an increase in the overall graybody emission.


IR Intensity variation during stressing from start to failure. Note the sharp on-set of intensity decrease indicating coupling.

Bruker Vertex 70 Spectrometer


7.7-10 μm 10.5-12.5 μm

Excess IR emission

## RESULTS

In our experiment in the Sierra Nevada, we used a field-deployable Bruker EM27 FT-IR spectrometer with a 8" mirror optics. We observed excess IR emission between 900-750 $cm^{-1}$ which was absent before stressing. Similarly laboratory experiments using a Bruker Vertex 70 equipped with a 2 m long articulated IR emission attachment achieved the same results.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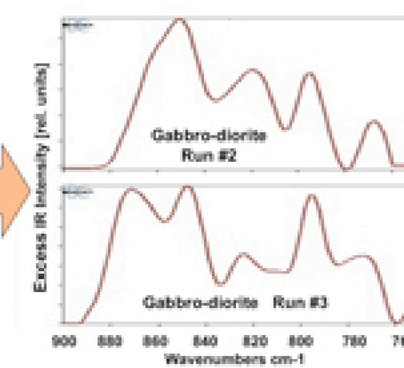
NASA IPP Grant, SETI Institute, SJSU, GraniteRock Corporation, Ron Strong and the staff of Bldg.211/212, Dr. Shulin Wang, and all Summer Interns, NASA Safety,


## CONCLUSION

During stressing of large rock boulders (granite and gabbro-diorite) we consistently observe an **increase in the graybody radiation** plus regions of **non-thermal excess IR emission** between 900-750 $cm^{-1}$ and 1300-1000 $cm^{-1}$ (11-12.5 μm and 7.7-10 μm) with a fine structure indicating narrow emission bands as reported earlier (*Freund et al.: Stimulated thermal IR emission from rocks: Assessing a stress indicator, eEarth, 2, 1-10 2007*). These observations suggest that the pre-earthquake "thermal IR anomalies" as seen in night-time satellite IR images around the epicentral regions of impending seismic activity contain a **thermal and a non-thermal component**.

The positions of the excess IR emission bands change slightly depending upon the area on the rock surface.





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Freund, F.T., et al. (2007), Stimulated thermal IR emission from rocks: Assessing a stress indicator, eEarth, 2, 1-10.

# Measurement of electromagnetic and RADAR effects during large-scale rock stress/fracture experiments


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## Abstract


In an attempt to replicate and understand naturally-occurring signals [1], experiments studying electromagnetic emissions have been performed in which small samples of gabbro or granite were stressed with a hydraulic press, and in field experiments with demolition agents. Additional experiments with hypervelocity impacts and other physical shocks have also shown that stress can induce electromagnetic phenomena.

When stress is experienced by igneous or high-grade metamorphic rocks, trapped electron vacancy defects are activated that when mobile behave as positive charge carriers. Responding to Coulomb forces, these mobile charge carriers diffuse out of the stressed subvolume and tend to plate out near the surface of the rock and modify the polarizability of the subsurface oxygen anions and, hence, the effective complex dielectric constant. The presence of such a quasi-metallic surface would be evidenced by a change in the RF reflection coefficient, for example if observed with a 1.2 GHz (L band) radar.


## Introduction & Methodology

A number of large samples of gabbro-diorite quarried from the Logan formation near Aromas, CA, between 0.5 and 1.5 cubic meters were transported to the NASA Ames Research Center in Mountain View, Ca. To prepare for the test, a rock sample is drilled with a series of 50mm diameter blind holes, pressure-washed, and placed upon a heavy-duty wooden pallet.

Rock #6

After drilling and washing

Ready to test

The figures above show a typical sample as it is prepared for the testing. One of the flat surfaces of the sample is surrounded by a frame of radar-absorbing mats, which have an RF attenuation of approximately 20 dB, to reduce the impact of surfaces that are not of interest. The radar is positioned 1 to 2 meters from the rock surface, and baseline data is acquired prior to the commencement of the rock breaking phase of the experiment.

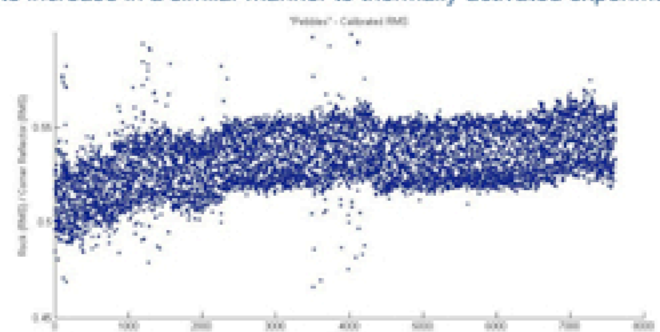
An expanding cement is mixed and poured into the bores, as the radar continuously monitors the reflection coefficient as the grout cures, and imparts up to 7000 tonnes/m2 expansive force, cleaving the rock into two or more pieces.

A 1.2 GHz ground-penetrating radar was used to observe and record an echogram for the experiment, from which the amplitude reflection coefficient was extracted for the rock surface. Steps to ensure stability included the use of an AC mains power stabilizer/UPS, and a corner-cube radar reflector to provide a constant reflection coefficient reference.

## Results & Conclusions

Samples of gabbro have been previously shown to have a marked increase in the radar reflection coefficient at 1.2 Ghz when heated above approximately 350°C [2]. Exposure to stress produces observed changes in reflection coefficient on the order of a few percent, as the stress builds up to the failure point. The plot below is the reflection data of rock sample #6 that has been normalized with respect to the reference reflector. After a stable baseline was established, the reflection coefficient was seen to increase in a similar manner to thermally-activated experiments.

After test



Start Finish

Future work will address improving the stability of the experiment and understanding the sudden shifts in the data.

## References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[2] C. Williams, G. Tsoflias, G. Cyr, R. Dahlgren, J. Keefner, and F. Freund, "Radar Reflectivity Changes of Rock Surfaces due to Thermally-Activated Charge Carriers: Contributing to the Understanding of the Magellan Venus Radar Reflectivity Data," AGU Fall Meeting 2009 [P33A-1277]


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